2nd International Workshop on High-Order CFD Methods

Summary of the C2.2 test case results

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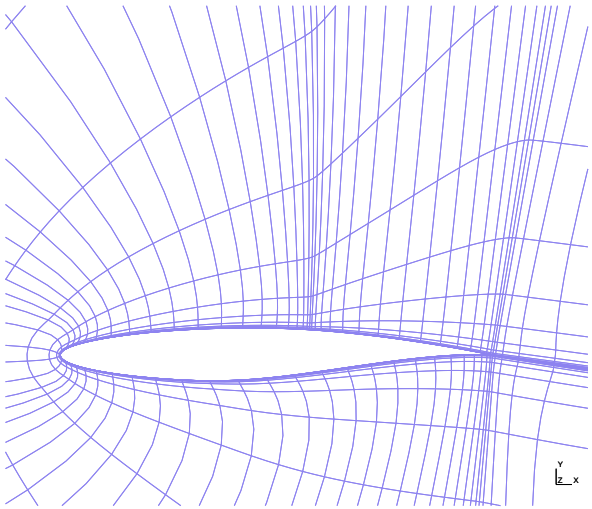
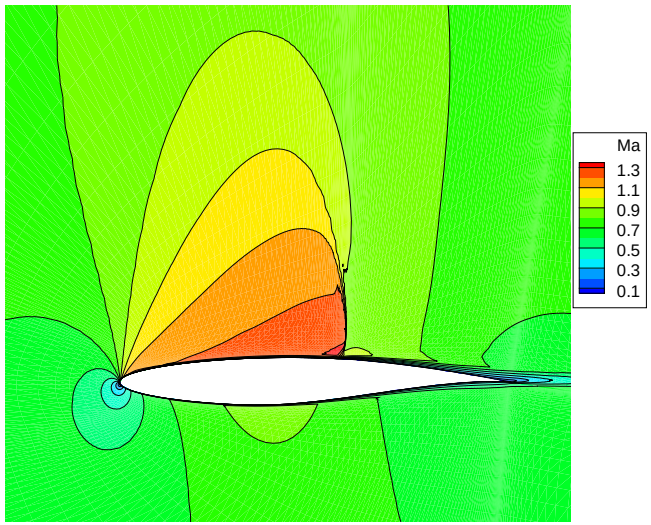
Test case C2.2

Transonic, turbulent flow over a RAE airfoil

- Ma $= 0.734$, Re $= 6.5 \times 10^6$, $\alpha = 2.79°$
- Data available from
  - DLR
  - INRIA
  - University of Michigan
- High order quadrilateral grids provided
  - INRIA: triangular grids, obtained from the provided quadrilateral grids





Test case C2.2
High Order solvers

	DLR	INRIA	UniMich
Discretization	Discontinuous Galerkin	Residual Distribution	Discontinuous Galerkin
Solver	Newton GMRES (ILU)	Non-linear LU-SGS	Newton GMRES (line-precond.)
Turbulence model	k–ω transition at 3% chord	Spalart-Allmaras fully turbulent	Spalart-Allmaras fully turbulent
Viscosity law	Constant	Constant	Sutherland
Shock treatment	Residual-based shock capturing	Non-linear scheme	Sub-cell shock capturing
Convergence	L2 (10^{-8})	$L2_\rho$ (10^{-10})	L1 ($10^{-7 \div 8}$)

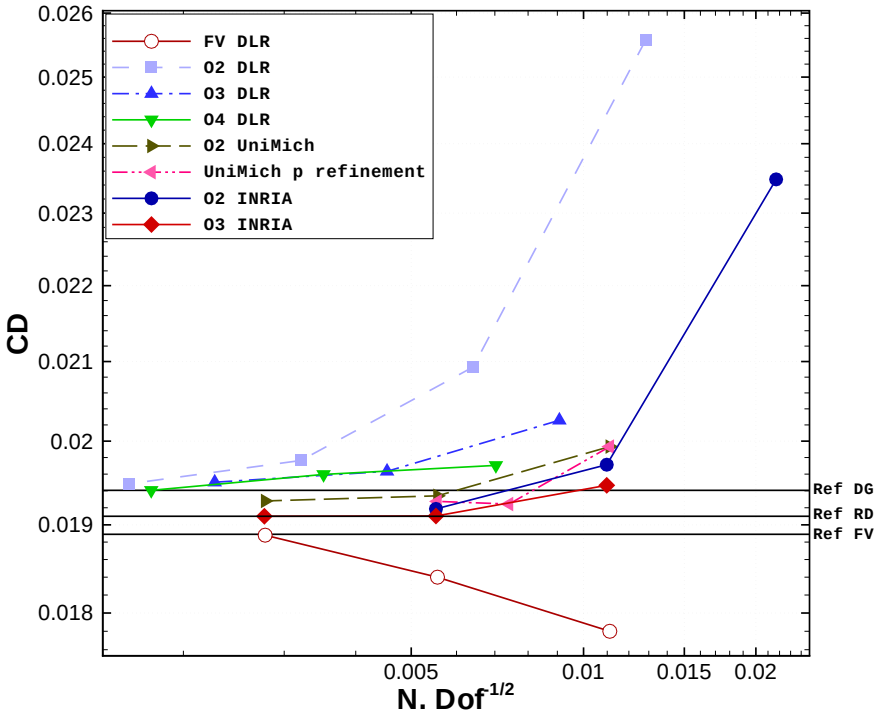
Test case C2.2

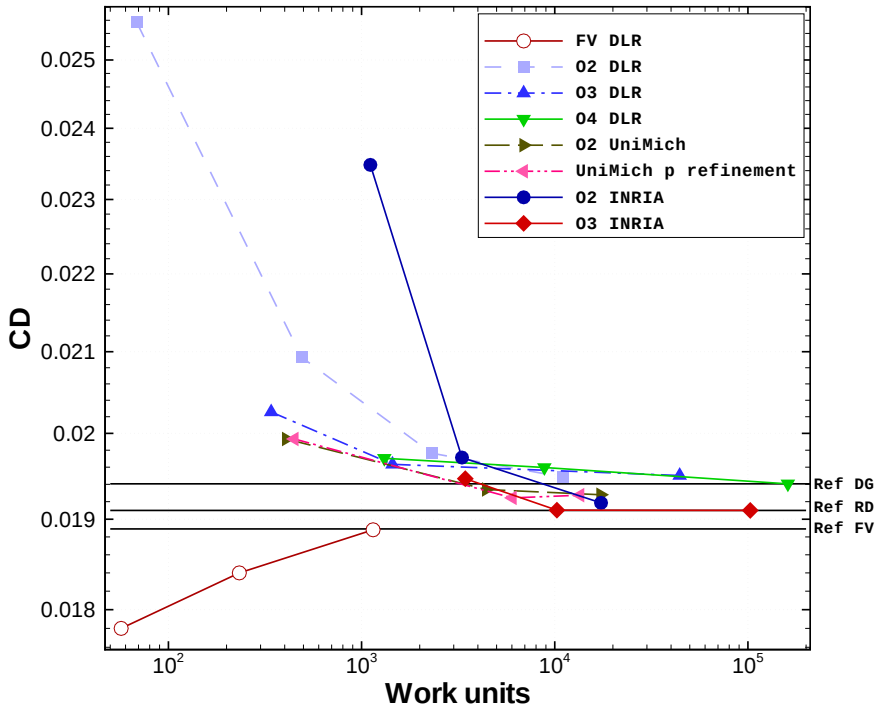
Reference Finite Volume solver

	DLR
Discretization	Finite Volume
Solver	Multi-Grid
Turbulence model	Spalart-Allmaras fully turbulent
Convergence	$L2_\rho$ (10^{-10})

Test case C2.2

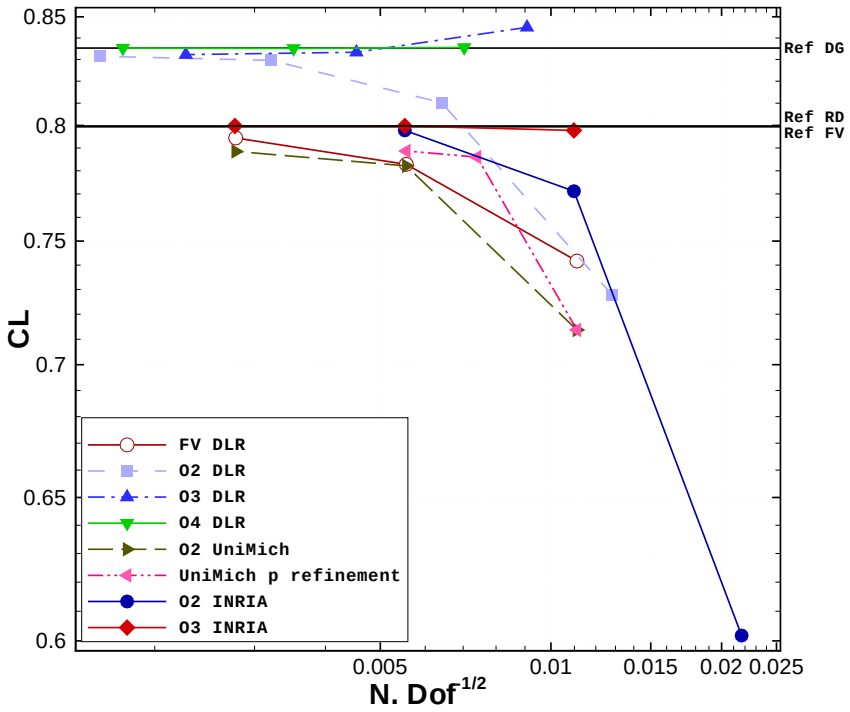
Uniform refinement: drag coefficient convergence

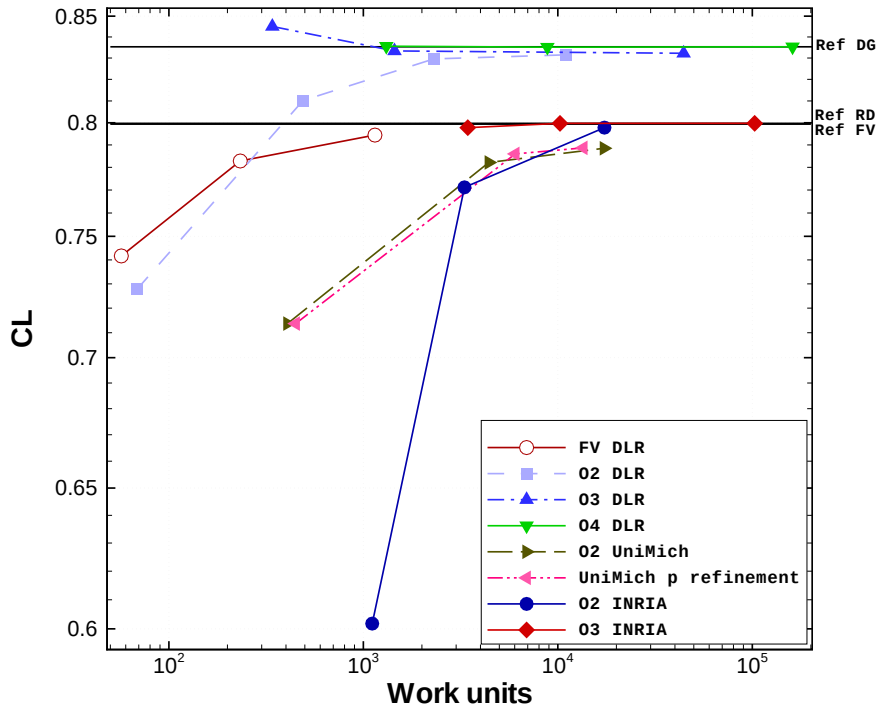




Test case C2.2

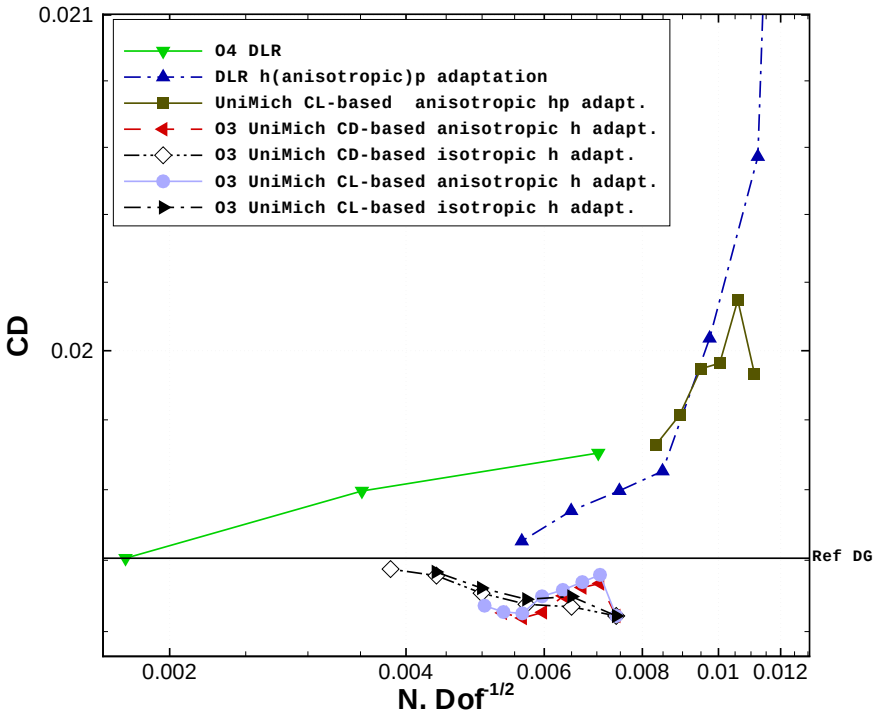
Uniform refinement: lift coefficient convergence

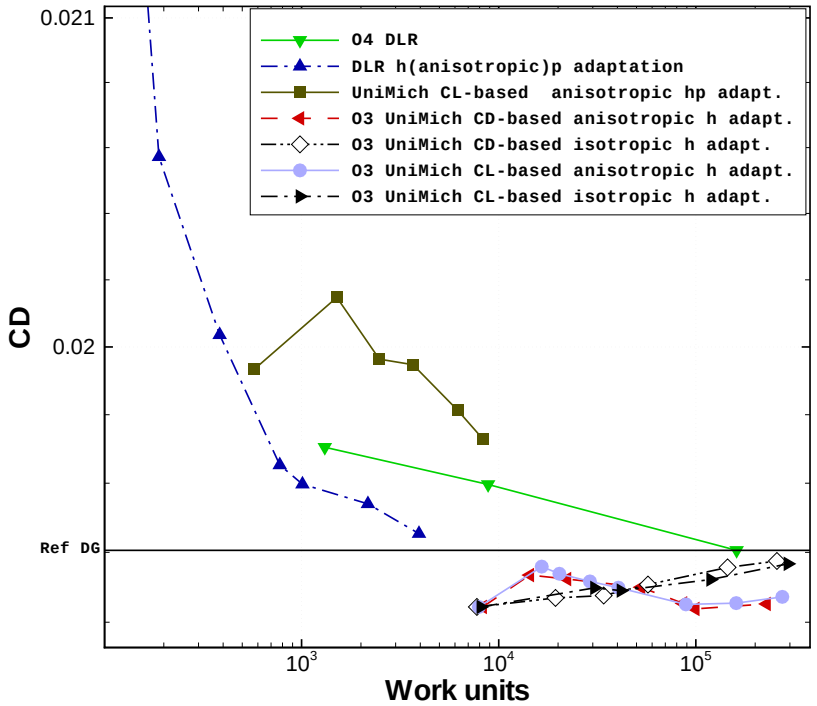




Test case C2.2

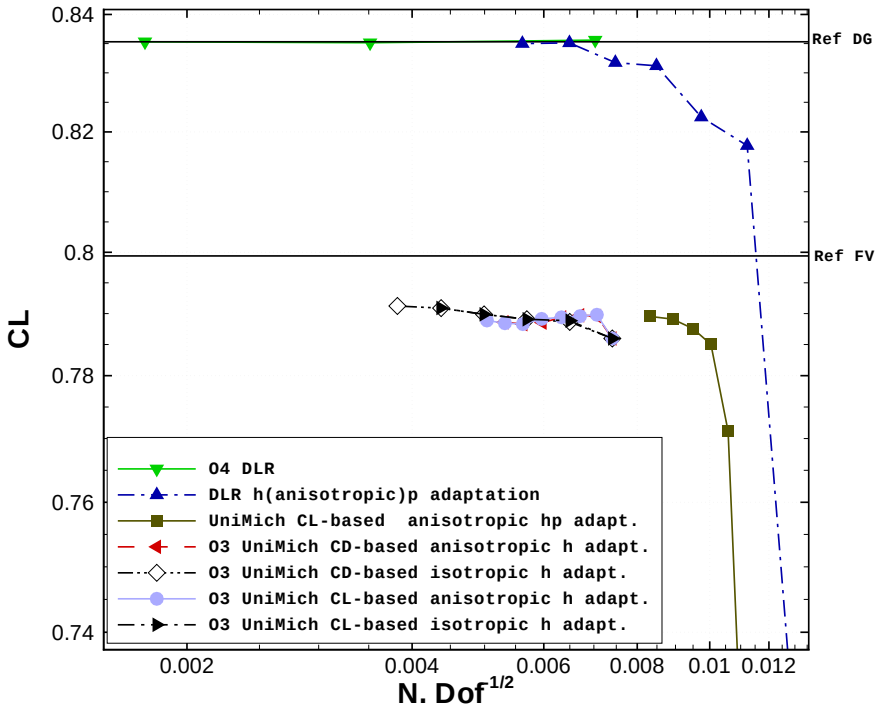
Adaptive refinement: Drag coefficient convergence

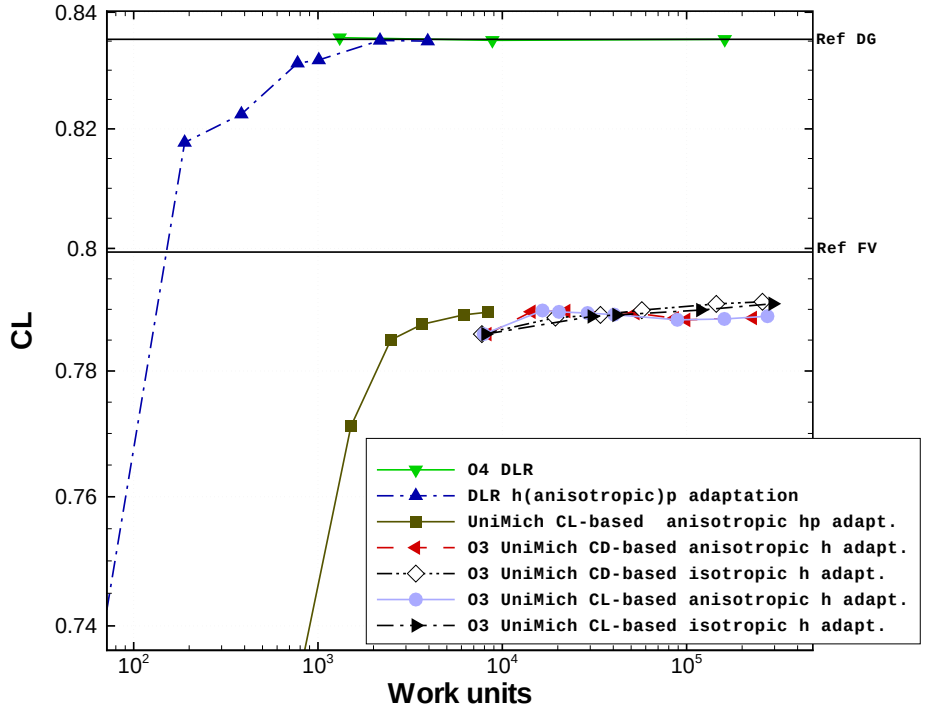




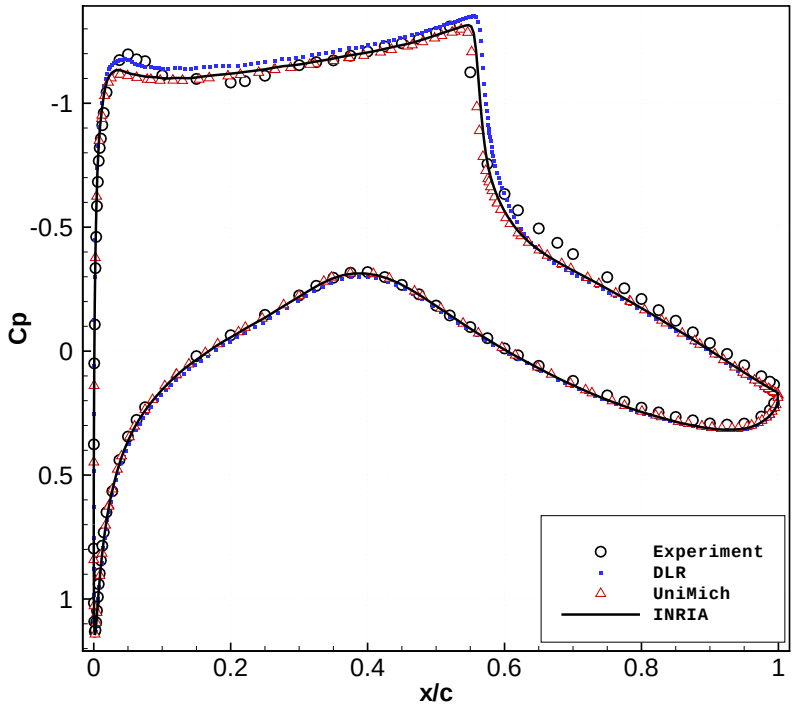
Test case C2.2

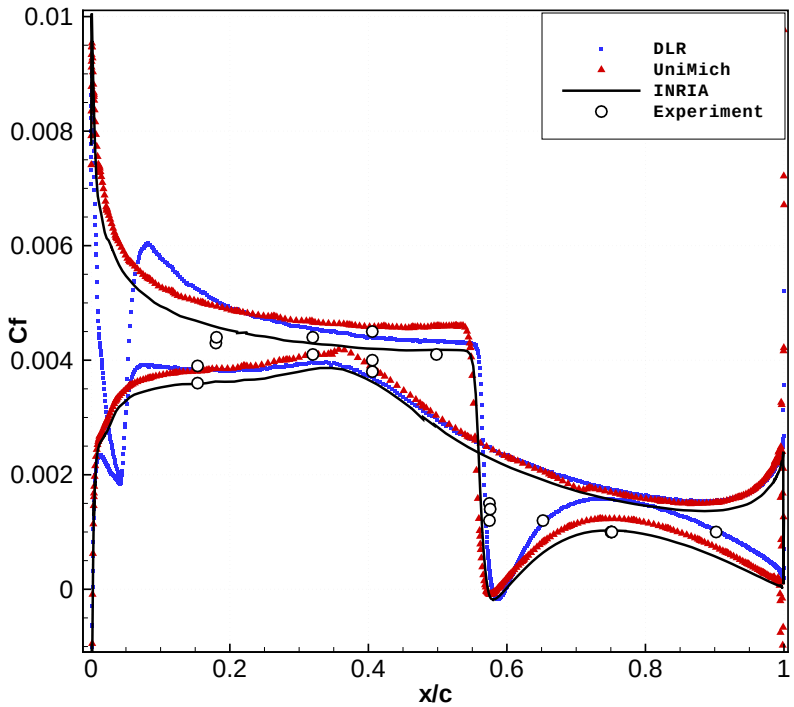
Adaptive refinement: Lift coefficient convergence





Test case C2.2
Conclusions





- Fully turbulent (INRIA & UniMich) and transition (DLR)
  - The higher peak of pressure and the bump of the skin friction at the leading edge of the airfoil for DLR are due to the transition
- Discrepancies in the shock position and differences in the skin friction distributions (transition, different turbulence models and viscous laws)

Test case C2.2
Conclusions

- Very difficult to compare results of different partners
  - Different modeling: turbulence models, viscosity, free-stream values
  - Different boundary conditions. Far-field correction
  - Effect of shock capturing?
- What are the reference values?
  - Difficult to compare errors
- Not clear, for this test case, the advantage of HO methods over standard FV, unless h/p adaptive refinement strategy is considered